TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 55

"AIRPLANE CRASHES: ENGINE TROUBLES".

A POSSIBLE EXPLANATION.

By

Stanwood W. Sparrow,
Automotive Power Plant Section,
Bureau of Standards.

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When the daily paper tells that a plane has crashed and states a definite cause such as the fracture of a fuel line or the collapse of a wing, public confidence in the safety of aviation is shaken. It is easy to believe, however, that defects so glaringly revealed will be corrected at once. The real blow to aviation comes when no satisfactory explanation for the accident is forthcoming. Knowledge of what is wrong must precede any intelligent effort to make a thing right. A wrecked plane bearing mute testimony to the existence of a fault and a confession of ignorance as to the nature of the fault tends to contradict assertions that aviation has outgrown the experimental stage. To bring attention to one possible cause of such unexplained accidents this note has been prepared for the National Advisory Committee for Aeronautics.

In testing airplane engines at the Bureau of Standards it has happened frequently that the engine performance became erratic when the temperature of the air entering the carburator was between $0^{\circ}C$ ($32^{\circ}F$) and $20^{\circ}C$ ($68^{\circ}F$). Investigation revealed the trouble to have been caused by the formation and

collection of snow somewhere between the entrance to the carburetor and the manifold, probably at the throttle. Experiments in the carburetor test plant had shown the possibility of this trouble. In fact, a glass portion of the induction system made it possible for one actually to see the snow as it collected.

Proof scarcely less convincing was obtained during engine tests. That something was wrong became apparent from a drop in power. The manifold depression, the difference between atmospheric pressure and the pressure in the manifold, was greater than that usually obtained at full throttle at this speed. At the same time, measurements showed the rate of air flow to be lower than usual. Inasmuch as both of these effects would be produced by throttling the engine, they gave a clue to the source of trouble. In some cases the snow would continue to collect until it shut the engine down while at other times after it had effected a decrease in power of from 25 to 50 per cent a portion would become dislodged and the engine would speed up. The test apparatus is arranged so that the air on its way to the engine passes over heating grids. If, while the power was still low, sufficient heat was applied to increase the air temperature 20°C (36°F) the power, manifold depression and air flow would soon regain their normal values. A few rather violent fluctuations of speed usually accompanied this period and can be attributed to the water passing into the combustion chamber as the snow melted.

Granting this trouble to be caused by the condensation of moisture from the air and the subsequent formation of snow, the removal of the moisture should prove as effective a cure as an increase in temperature. Fortunately it was possible to do this and thus check the validity of this supposition as to the origin of the trouble. The engine test apparatus includes refrigerating coils which enable all the air taken by the engine to be cooled to below -20°C (-4°F). This air is then reheated to the desired temperature. Air when cooled to -20°C (-4°F) contains almost no moisture and no opportunity is offered for it to collect any during its passage from the heating grids to the engine. Under these conditions, the engine operated satisfactorily at those temperatures at which difficulty was experienced with the air from which the moisture had not been removed.

The more serious the manifestations of this trouble, the more difficult it becomes to secure accurate data for record. Fluctuations of speed are violent and a stalled engine is usually the final result. A record of a few instances where it was possible to hold the speed reasonably constant are given as examples of the trouble in its milder stages. On February 14, 1921, with the engine operating at part throttle at 1800 r.p.m. it was noted that the power was decreasing. At 1:06 P.M. readings of carburetor air temperature and manifold depression showed the former to be 10°C (50°F) and the latter

25.0 cm. (9.84 in.) of mercury. Heat was applied and at 1:08 P.M. the air temperature had risen to 38°C (100°F) and the manifold depression had dropped to 6.8 cm. (2.68 in.). Again the temperature of the air was allowed to drop and again a drop in power and increase in manifold depression resulted. With the speed maintained at 1800 r.p.m., the throttle was opened wide and readings taken showing the air temperature to be 10°C (50°F), the manifold depression 11.1 cm. (4.37 in.) and the brake horse power 86. Within two minutes, the application of of heat had resulted in dropping the manifold depression to 5.6 cm. (2.20 in.) and in raising the brake horse power to 185. The forgoing results were all obtained at air densities corresponding to ground level. Similar conditions were found on February 23, at an air density corresponding to an altitude of 5,000 feet with the engine operating at full throttle at 1800 r.p.m. With the air at a temperature of 30°C (86°F), the manifold depression was 2.9 cm. (1.14 in.) and the brake horse power was 156. Eight minutes after the heating was discontinued, the air temperature had become 8°C (46°F), the manifold depression 5.1 cm. (2.01 in.) and the brake horse power 120.

While in all of these instances it was a change in weight of charge that caused the drop in power, the magnitude of the decrease may have been influenced by another factor, a change in mixture ratio. If a carburetor does not maintain the air-fuel ratio constant at reduced loads, any unintentional throttling involves a departure from the desired mixture quality

as well as a reduction in mixture quantity. To the reader familiar with carburetors in which changes in the area of a small passage between the float chamber and throat effect the mixture ratio changes, still another source of danger has doubtless suggested itself. This danger is that a collection of snow may block the connecting passage and cause a serious change in air-fuel ratio.

Discussion thus far may have emphasized unduly loss of power instead of what is probably the more serious effect, excessive fluctuations in power. Under these conditions a pilot is in exactly the same position as though his engine were controlled by a lunatic, opening and closing the throttle at will. Yet, in case of an accident, before an examination could be made the snow would have melted leaving no evidence to confirm the pilot's report of trouble.

It is hardly worth while to attempt to predict from theoretical considerations at what temperature the trouble from snow formation will be most pronounced. It does seem desirable, however, to consider how much additional external heating is necessary to give reasonable assurance that the trouble will not occur. The weight of water vapor that a unit volume of air can contain decreases with decrease in temperature and the surplus condenses. Obviously if the drop in temperature be prevented there can be no condensation. The problem is to supply sufficient heat to completely vaporize the fuel so that no heat for this purpose need be withdrawn from the mixture.

If the heat of vaporization of aviation gasoline be 75 cal. per gram (135 B.t.u. per pound)* complete vaporization will produce a drop in mixture temperature of 26°C (47°F) with an air-fuel ratio of 10 to 1 and a drop of about 14°C (25°F) with an air-fuel ratio of 20 to 1. It is safe to assume that the mixture ratio used will fall within these limits. The above calculation assumes all the fuel vaporized and all the heat used in vaporizing the fuel to be supplied by the mixture, while usually a portion of this heat is supplied externally. From these considerations it appears that the addition of an amount of heat sufficient to increase the mixture temperature 25°C (45°F) should prove a reasonable guarantee of immunity from this trouble. The power loss that this would entail should not exceed 5 per cent.

This note is not intended as a sweeping recommendation of additional air heating for every airplane engine. Such a course would be akin to prescribing medicine for a patient without first being assured that he was really sick. The aim is to call attention to a "disease" to which aviation engines are subject, to describe its symptoms, and to emphasize its seriousness. Methods of prevention or cure can be consigned with safety to those vitally concerned.

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* Ricardo, Automobile Engineer, February, 1921.